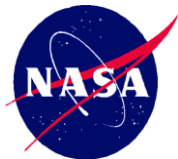


# **James Webb Space Telescope (JWST) Integrated Science Instruments Module (SIM) Electronics Compartment (IEC) Conformal Shields Composite Bond Structure Qualification Test Method -Extended Abstract-**

**NASA Structures, Loads & Dynamics, and Mechanical Systems (SLaMS)  
Young Professional (YP) Forum 2015**

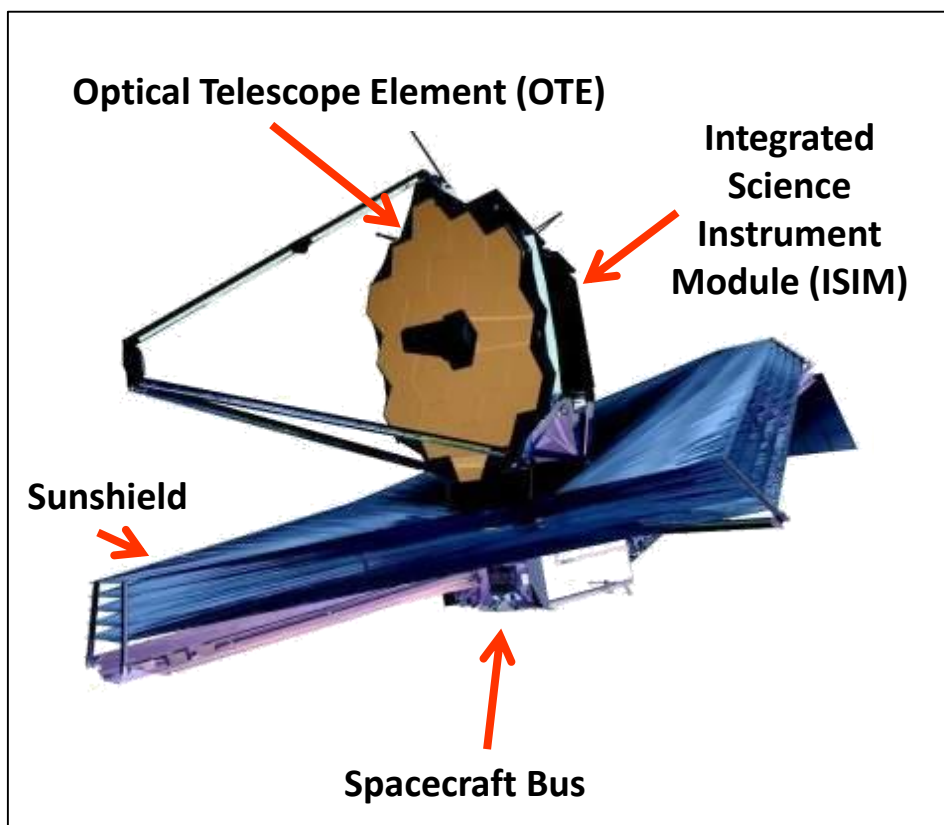
**Calinda Yew  
NASA GSFC Code 549  
Environmental Test & Integration Branch**

**Matt Stephens  
Genesis Engineering Solutions  
JWST ISIM IEC I&T Lead Mechanical Engineer**



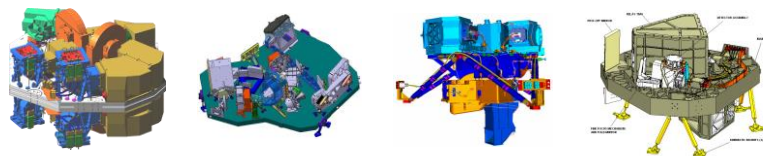
- **IEC Conformal Shields Frame Description**
- **Purpose of Testing the Structure**
- **Thermal Verification of Bonded Frames**
  - Bond Failure Results
  - Improved Test Method
  - Bond Repairs
  - Repaired Bonds Test & Results
- **Conclusions**

## ***The IEC Conformal Shields Frame is a structural component of the James Webb Space Telescope (JWST)***



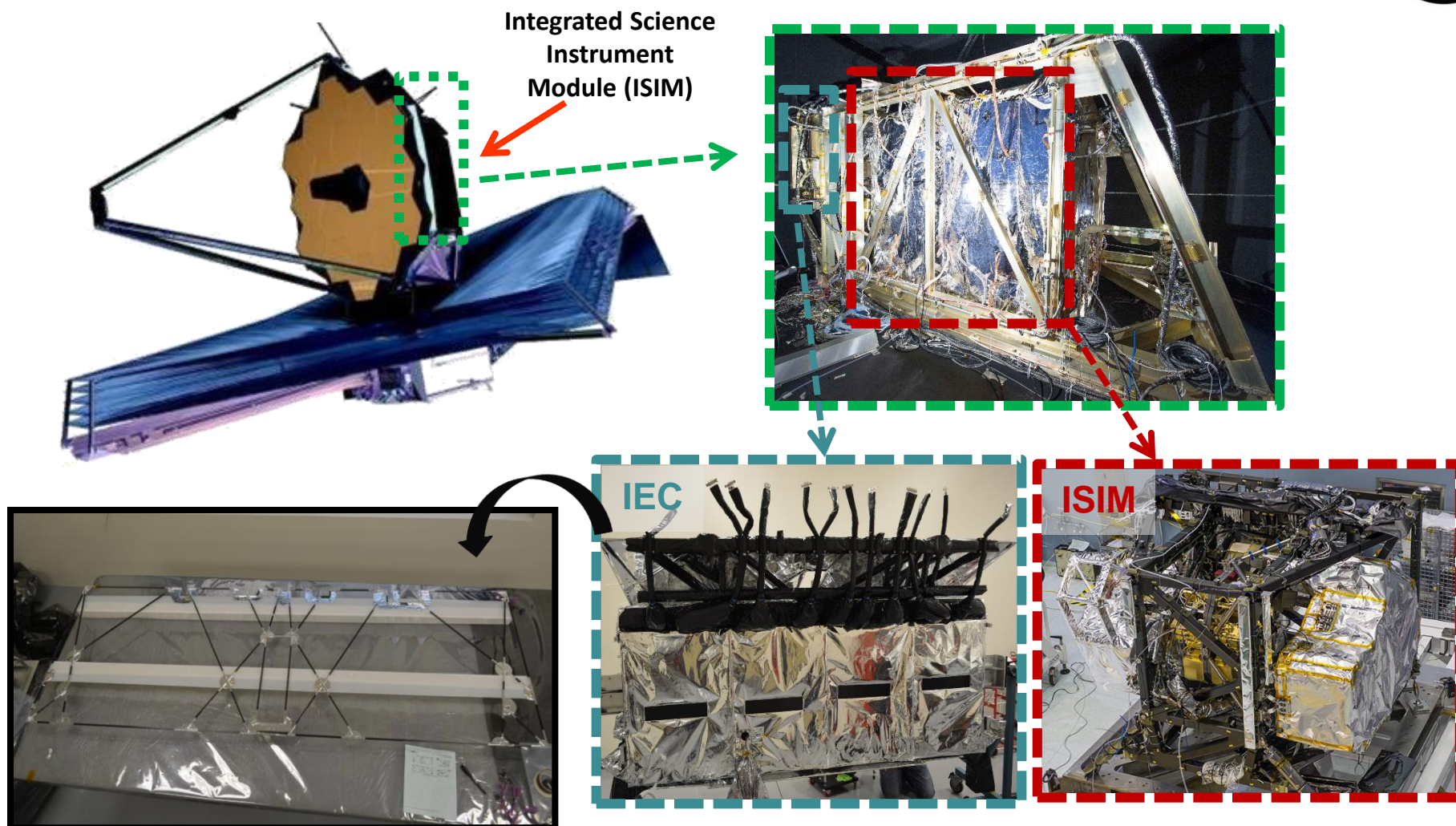
### **JWST Mission Objective**

Study the origin and evolution of galaxies, stars & planetary systems:  
*Optimized for infrared observations  
(0.6 – 28  $\mu\text{m}$ )*



### **Four Science Instruments (ISIM)**

- Near Infrared Camera (NIRCam)
- Near Infrared Spectrograph (NIRSpec)
- Mid-Infrared Instrument (MIRI)
- Fine Guidance Sensor (FGS)

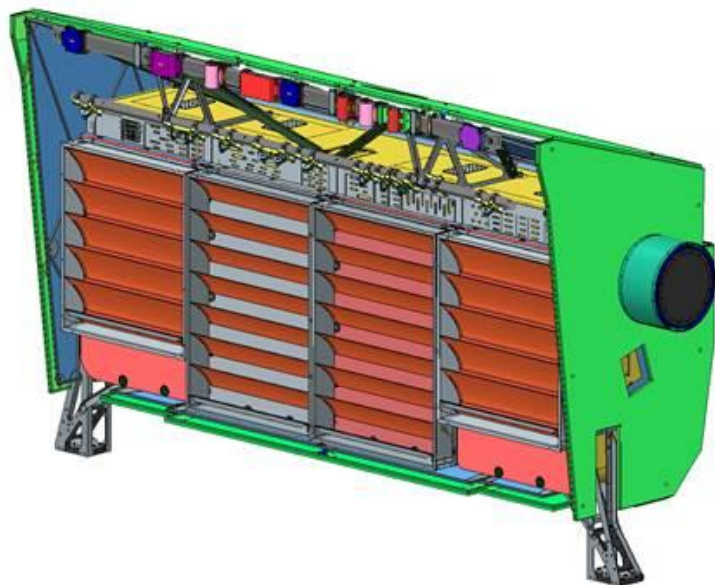


The function of the bonded composite frames is to provide the structure on which multi-layer insulation (MLI), called Conformal Shields, mounts

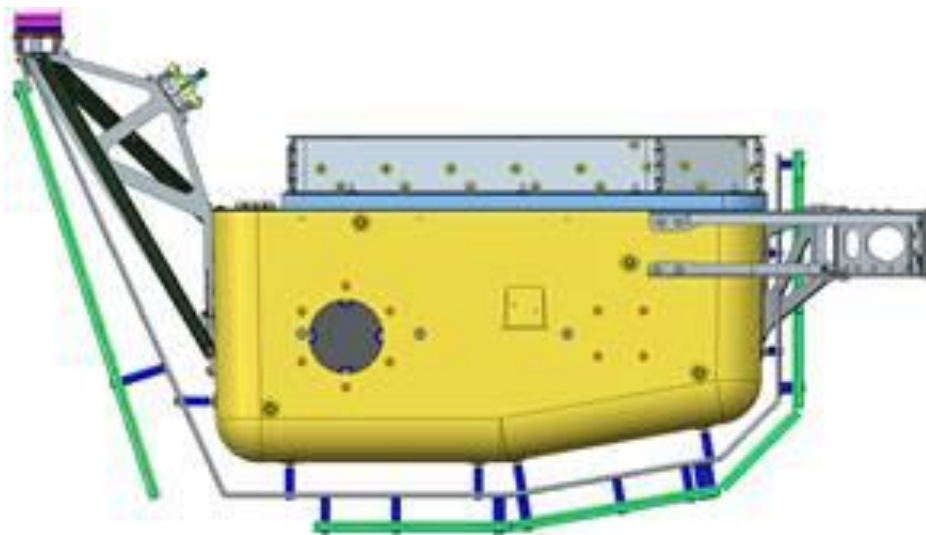


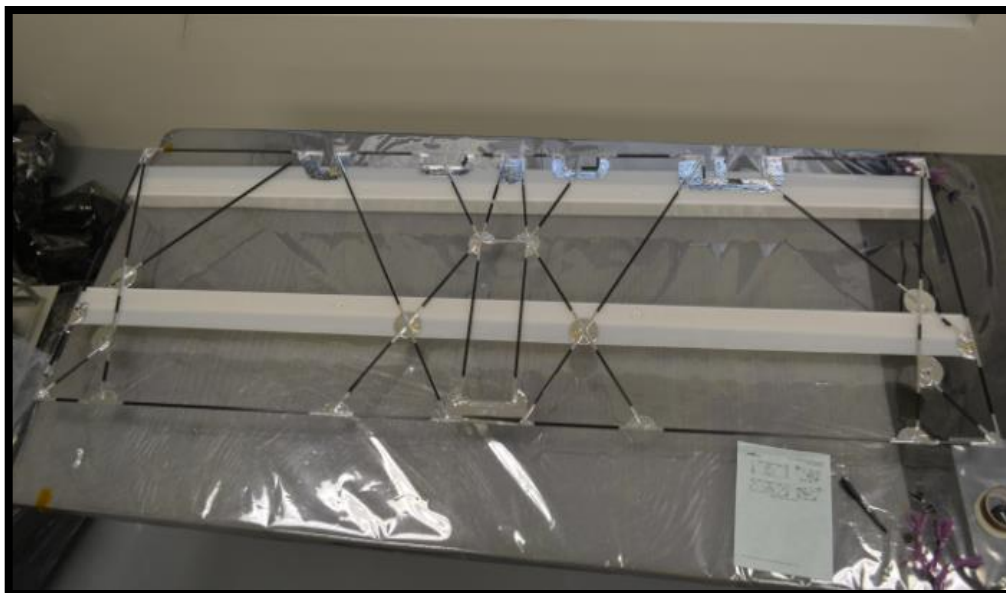
Conformal shields structure is critical to the thermal function of the IEC:

- IEC is a room temperature heat source in the middle of critically sensitive, tennis court size observatory
- Heat must be directed away from sensitive cryo-instruments



IEC flight configuration



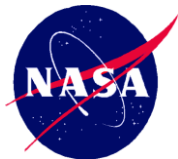


## ***Frames construction***

- 1/4" OD carbon fiber square tubes
- 1/16" thick carbon fiber gussets

## ***Bonded joints***

- Hysol EA 9394
- Excess adhesive squeezed out



# Purpose for Testing IEC Conformal Shields Frame

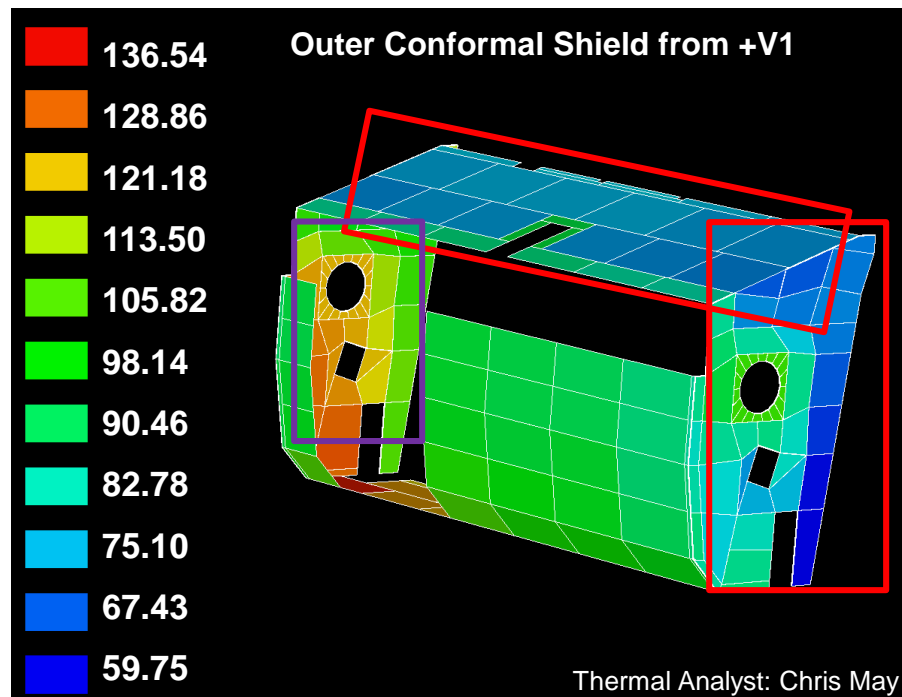
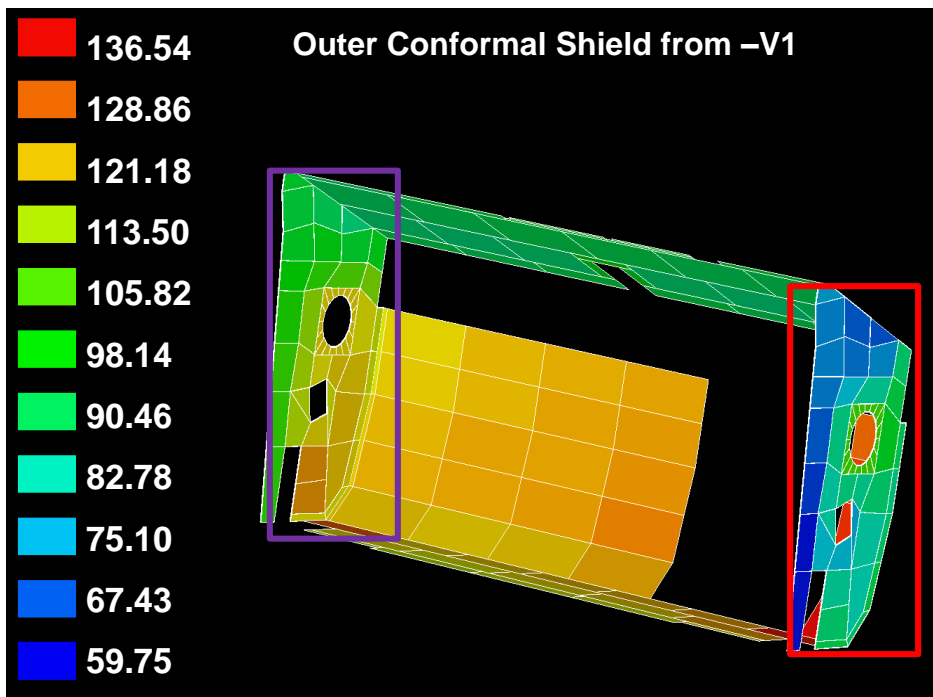
---



- **Verifies bonded joints fulfill Mission Assurance Requirements per JWST-RQMT-002363**
    - MAI-405: If the use of adhesives is planned, proper adhesive selection for the operating environment, surface preparation, bond line thickness, and component configuration shall be made and indicate positive margins with an ultimate factor of safety (FS) of 1.5 with analysis.
    - MAI-406: All bonded interfaces shall be strength test verified.
  - **Reduce risk of in-flight bonded joints failure**
- **OPERATING ENVIRONMENT: EA 9394 needs to be evaluated for cryo-susceptibility**
- Need to confirm flight temperatures to perform thermal vacuum testing
- **STRENGTH TEST: An equivalent flight load needs to be determined**
- Pull test to 1.4 flight loads (per NASA-STD-5001A)

Thermal test requirement is based on JWST observatory thermal model:

- Achieve protoflight levels: 10K margin over flight operational temperatures per General Environmental Verification Standard (GEVS); GSFC-STD-7000
- Achieve  $-162^{\circ}\text{C}$  (111K) on 17 frame structures &  $-190^{\circ}\text{C}$  (83K) on 3 frame structures



Thermal Analyst: Chris May

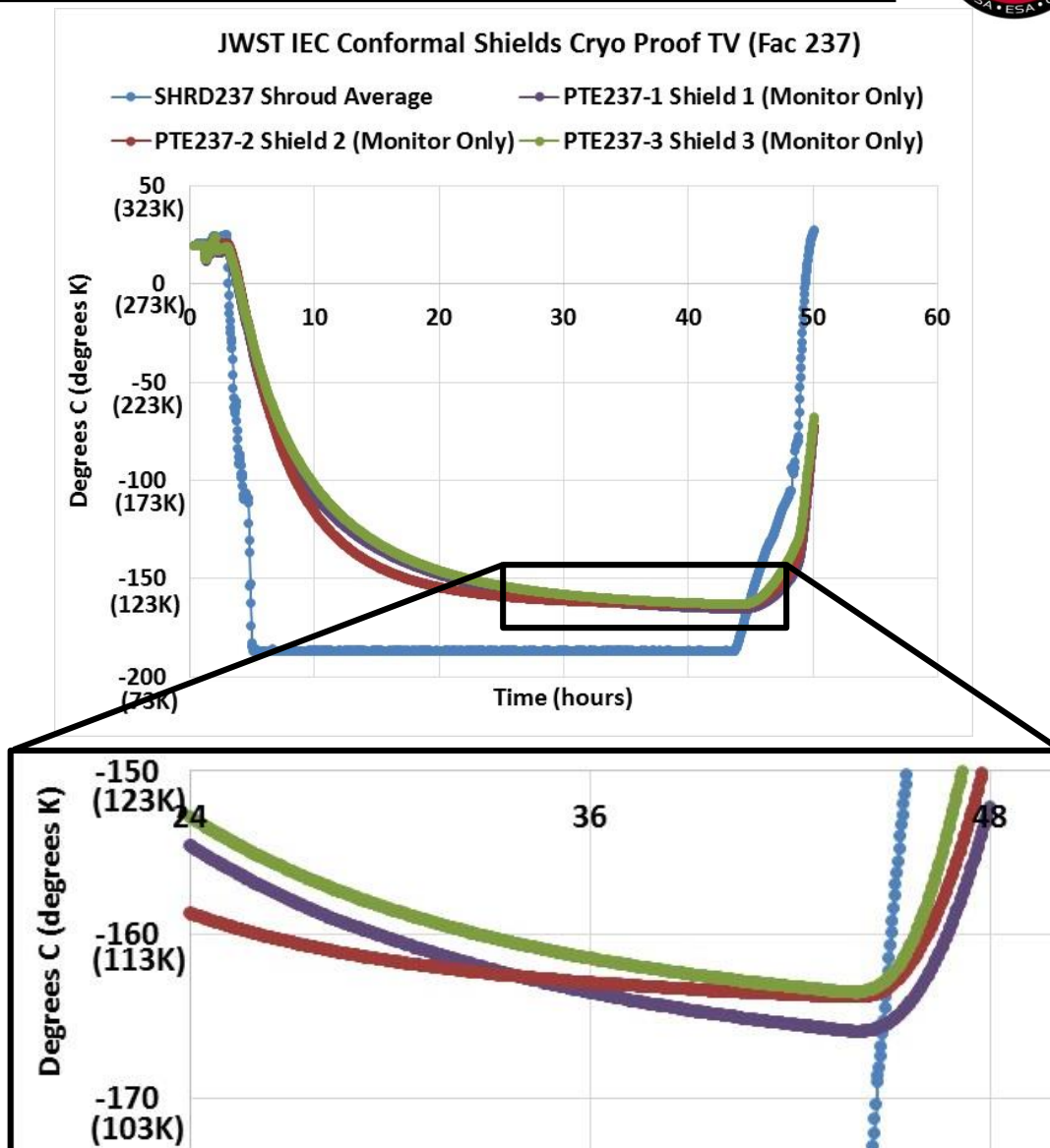
Outer layer of the MLI predicated to lower temperatures (59.75K)

But, inner side of the MLI correlates to actual frame temperature (~93K)





NASA GSFC Chamber 237 thermal vacuum chamber in flooded LN<sub>2</sub> shroud environment



LN<sub>2</sub>-flooded shroud at -187°C (86K) achieved -166°C to -163°C (107K to 110K) on frames

**Post-cryo pull tests (2 lbs) performed at 2 locations for each frame section**



**Pass/Fail Criteria – Failed if bond weakening is indicated by:**

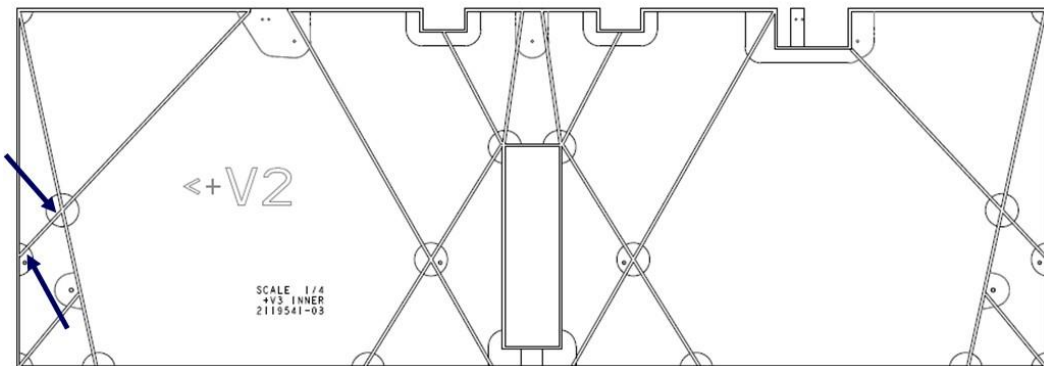
- Sudden decrease in load during pull test
- Visual inspection

Bond failures occurred in a total of 6 locations on 3 of the structures

**+V3 Inner Conformal Shield**

**2119541-03**

**Post Cryo Bond Failure Locations (x2)**

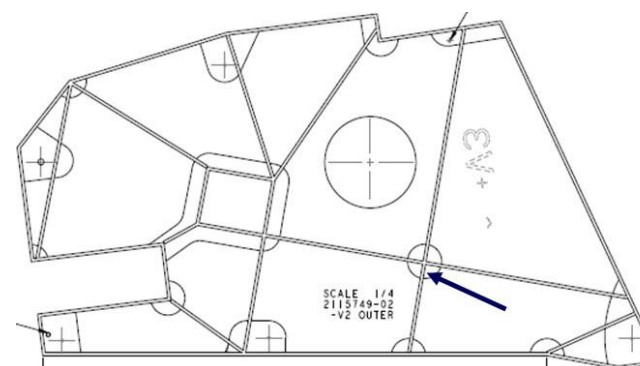


111K temp req'd

**-V2 Outer Conformal Shield**

**2115749-02**

**Post Cryo Bond Failure Location (x1)**

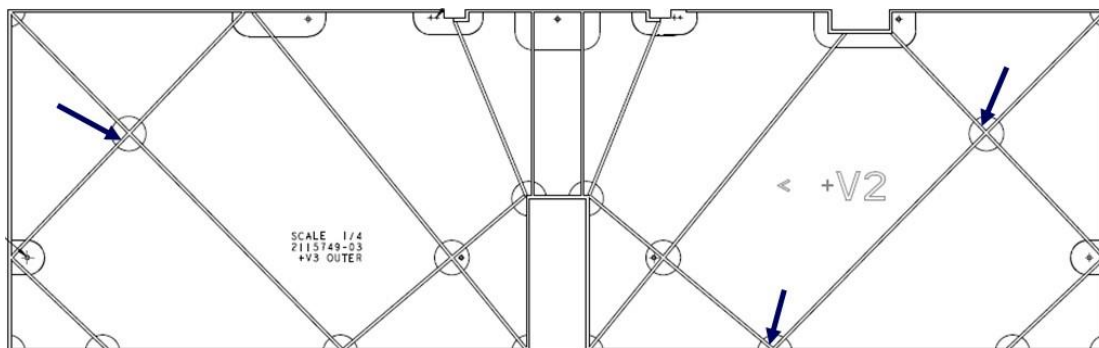


83K temp req'd

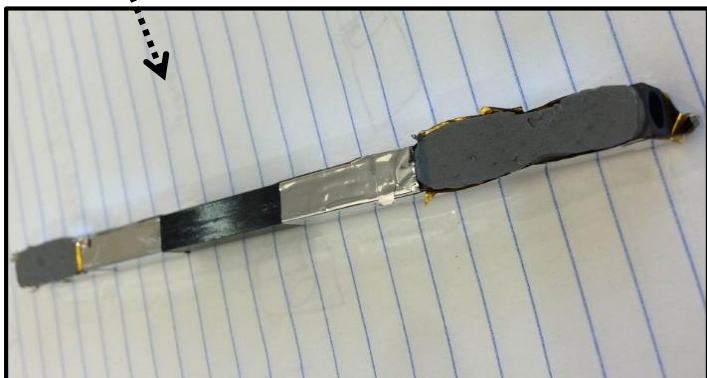
**+V3 Outer Conformal Shield**

**2115749-03**

**Post Cryo Bond Failure Locations (x3)**

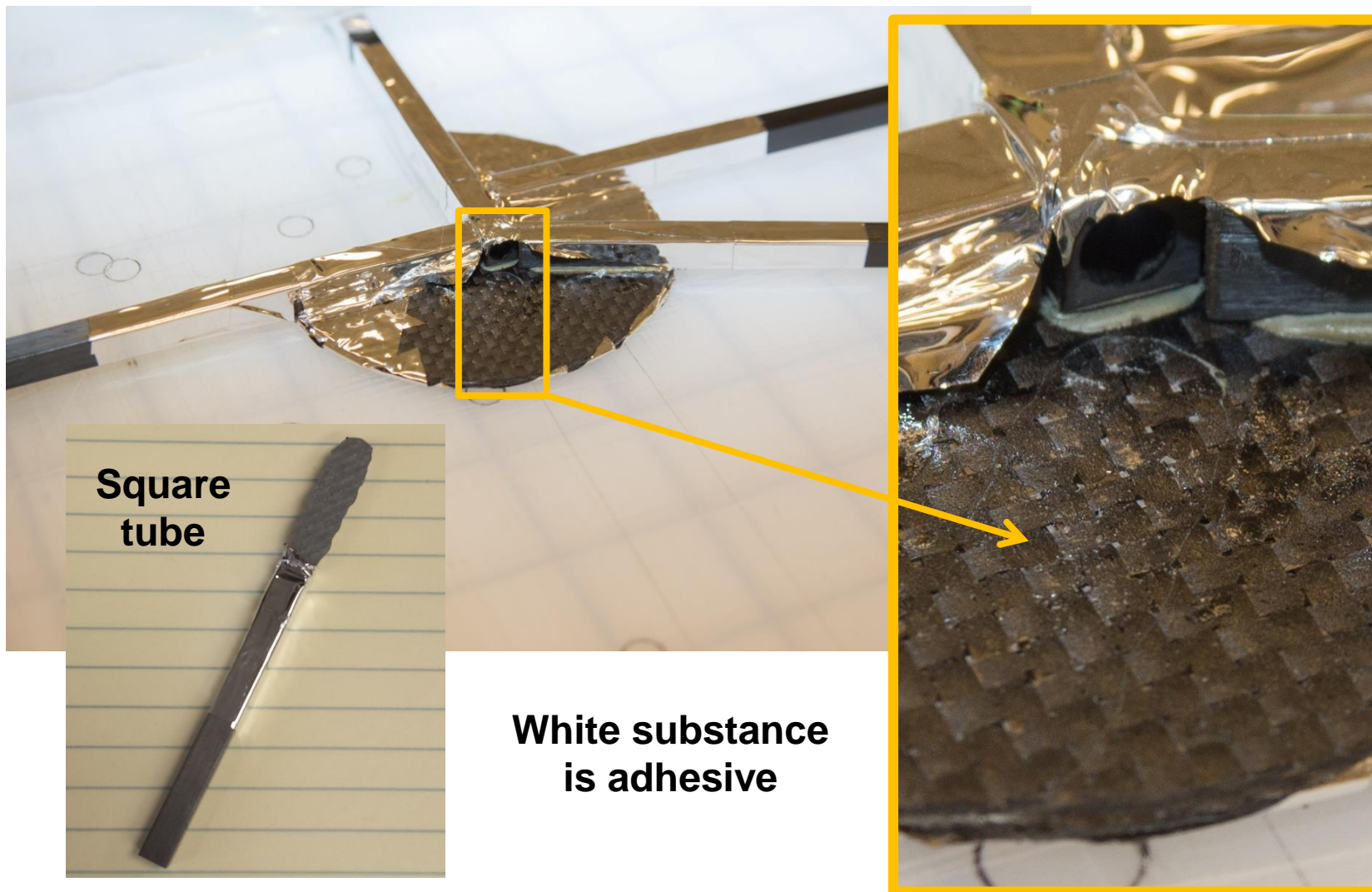


83K temp req'd



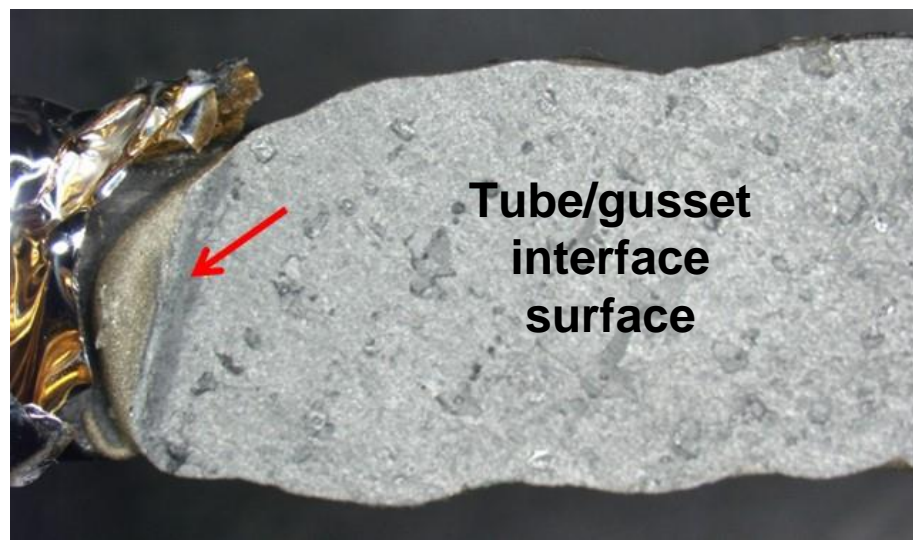
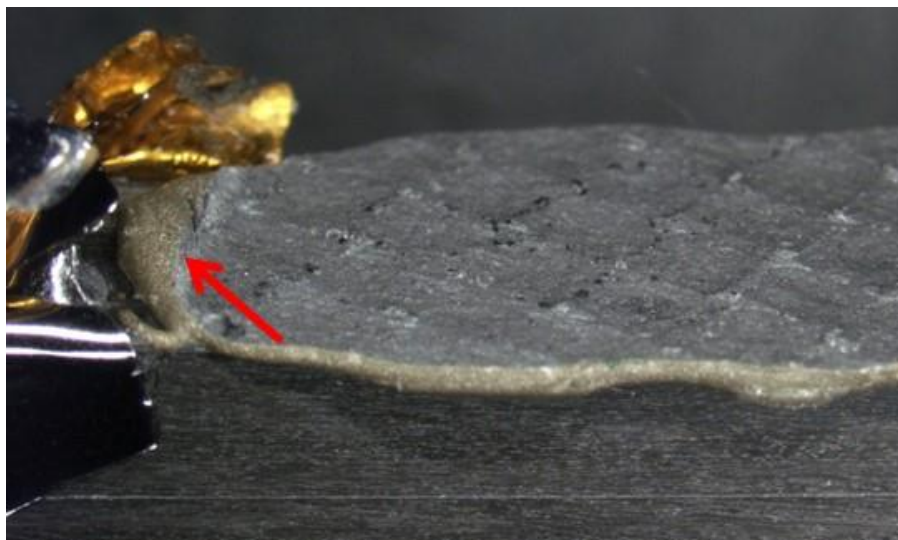


## Failure at square tubes to gussets bond



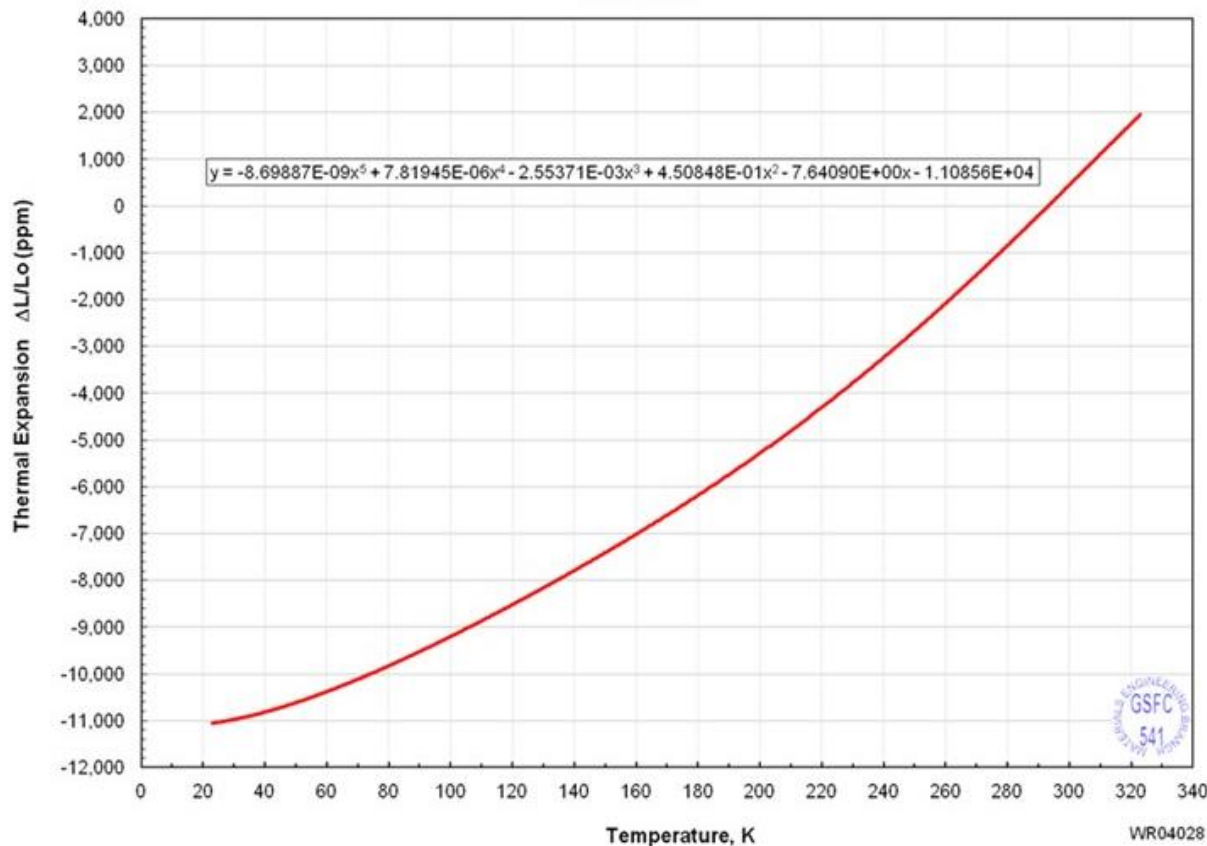
## Failure Analysis

- Failure Mode: Adhesive failure due to stress concentration at fillets
- Large fillets were all around the bond line
- Crack started at the gusset edge fillet (arrows) & propagated





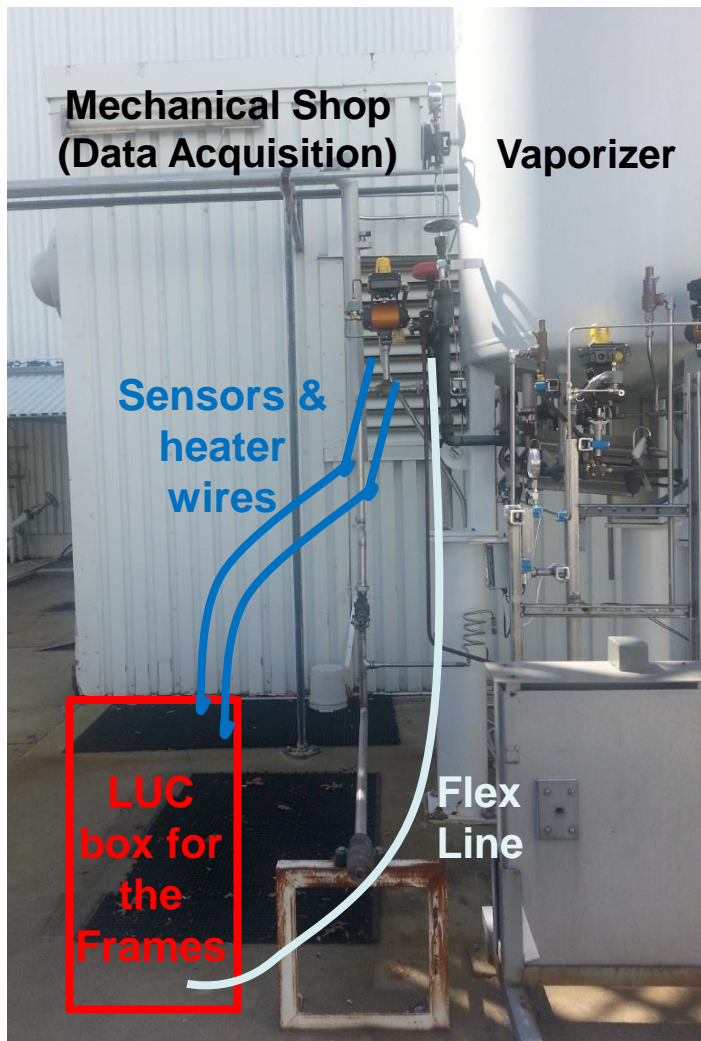
Thermal Expansion of Hysol EA9394  
JWST-ISIM  
8-18-2004



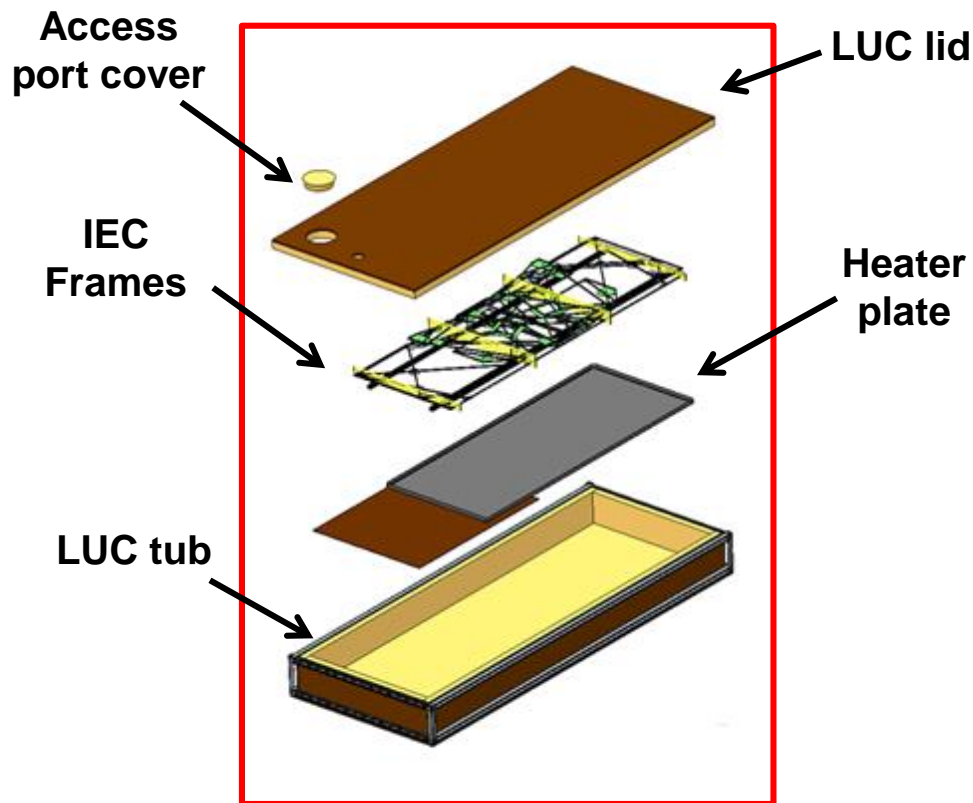
**Why is it a big deal to go from 110K to 83K?**

**CTE data for EA 9394 indicates about 0.8% change in dimensions from 110K to 83K**

**Since chamber shroud can only achieve -187°C (86K) and thermal requirement is to achieve 83K on the hardware → Need new method to achieve 83K**

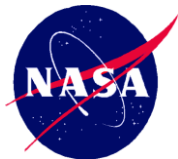


## LUC = LN<sub>2</sub> Unpressured Container



Fill LUC tub with GN<sub>2</sub>, then LN<sub>2</sub>

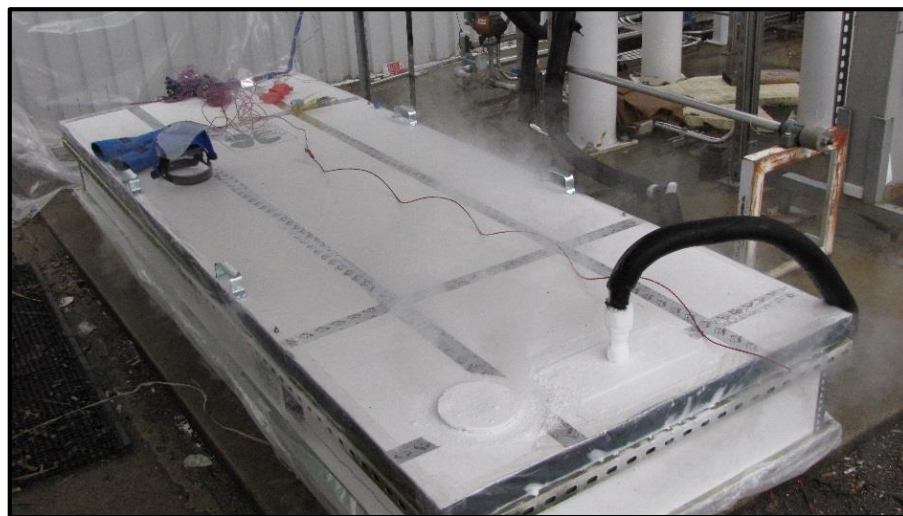
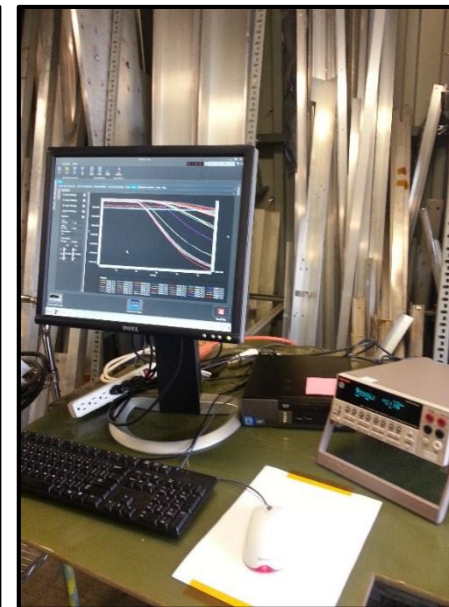
Must achieve 83K for frames with failed bonds + those with 83K requirement  
(total of 4 frames)



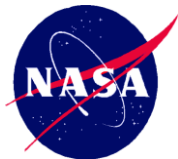
# Improved Test Method



## Actual Atmospheric LN<sub>2</sub> test set-up:





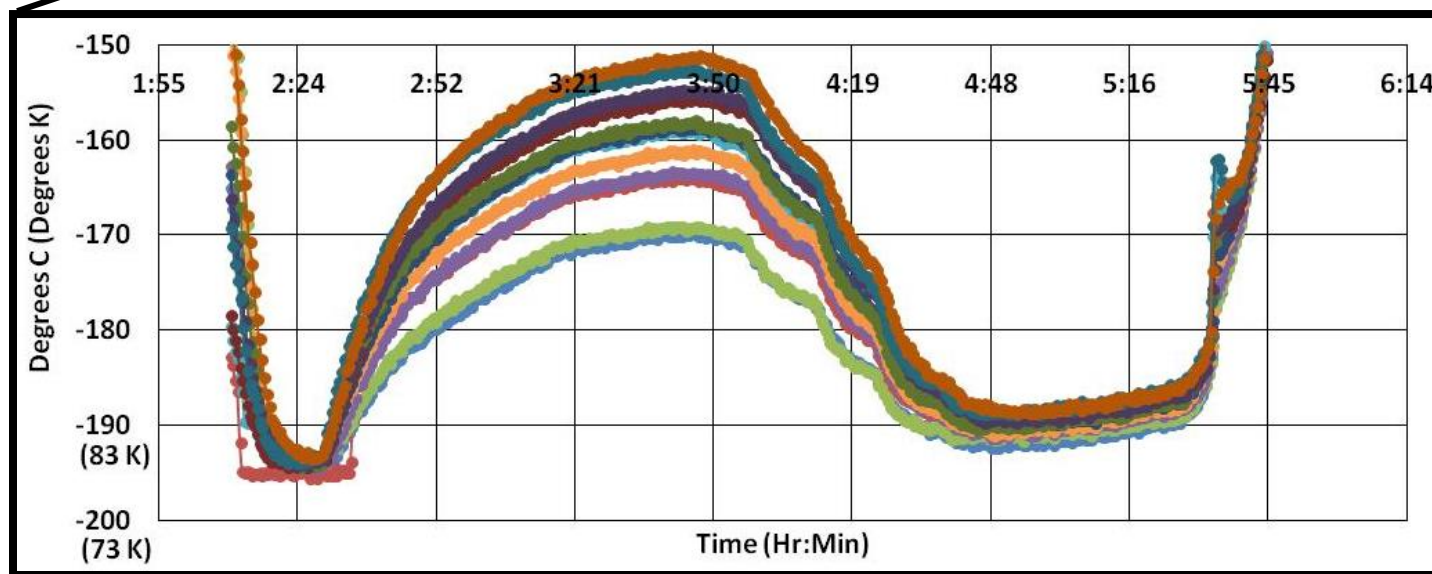
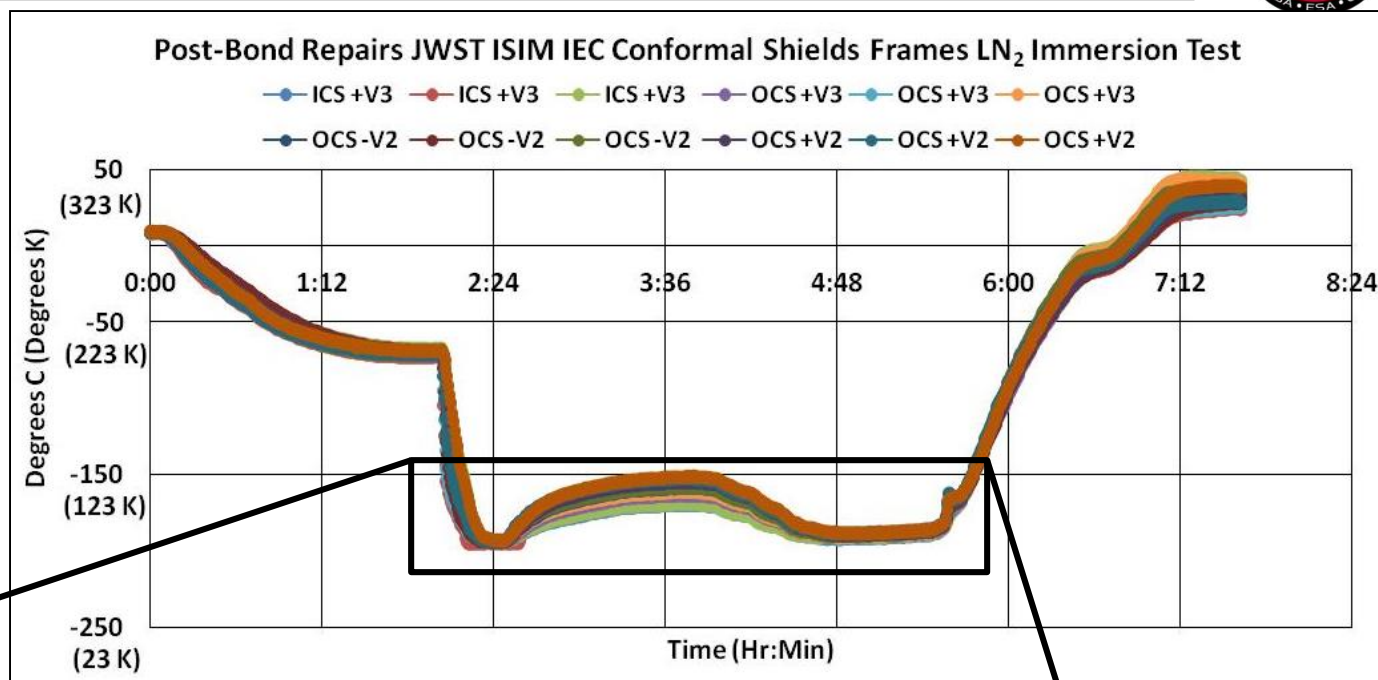


# Atmospheric LN<sub>2</sub> Test Results



(1) Thermal test results: Achieved 78K-80K, exceeds protoflight levels

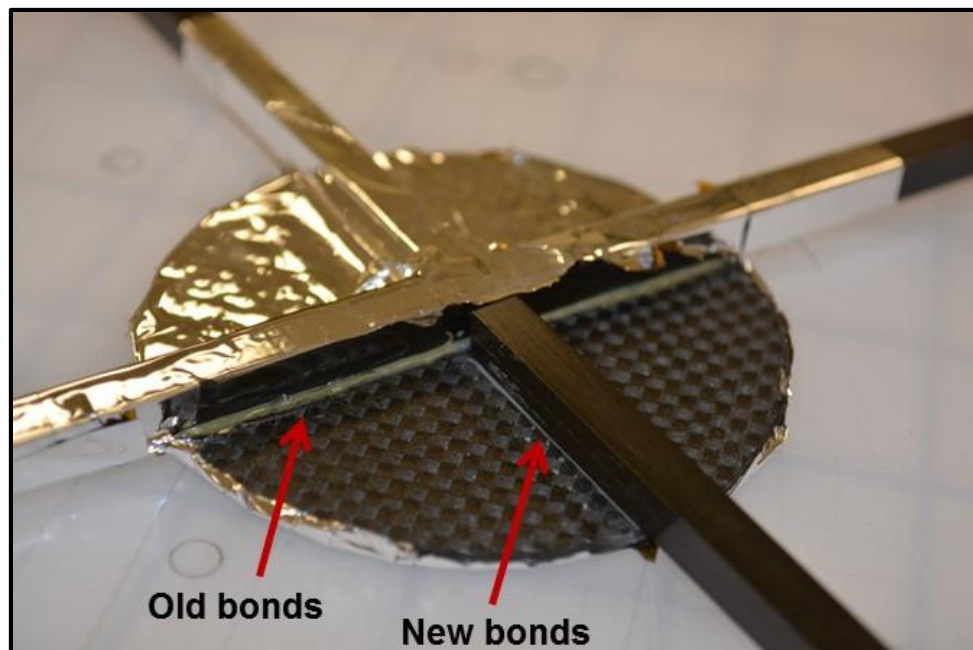
(2) Mechanical test results were also positive: NO NEW BOND FAILURES



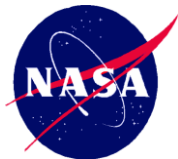
- Tubes replaced with new ones
- Bond line and squeeze out controls



- Must re-test to qualify flight structure
- Cryo-test: Shields achieved 107K – 110K





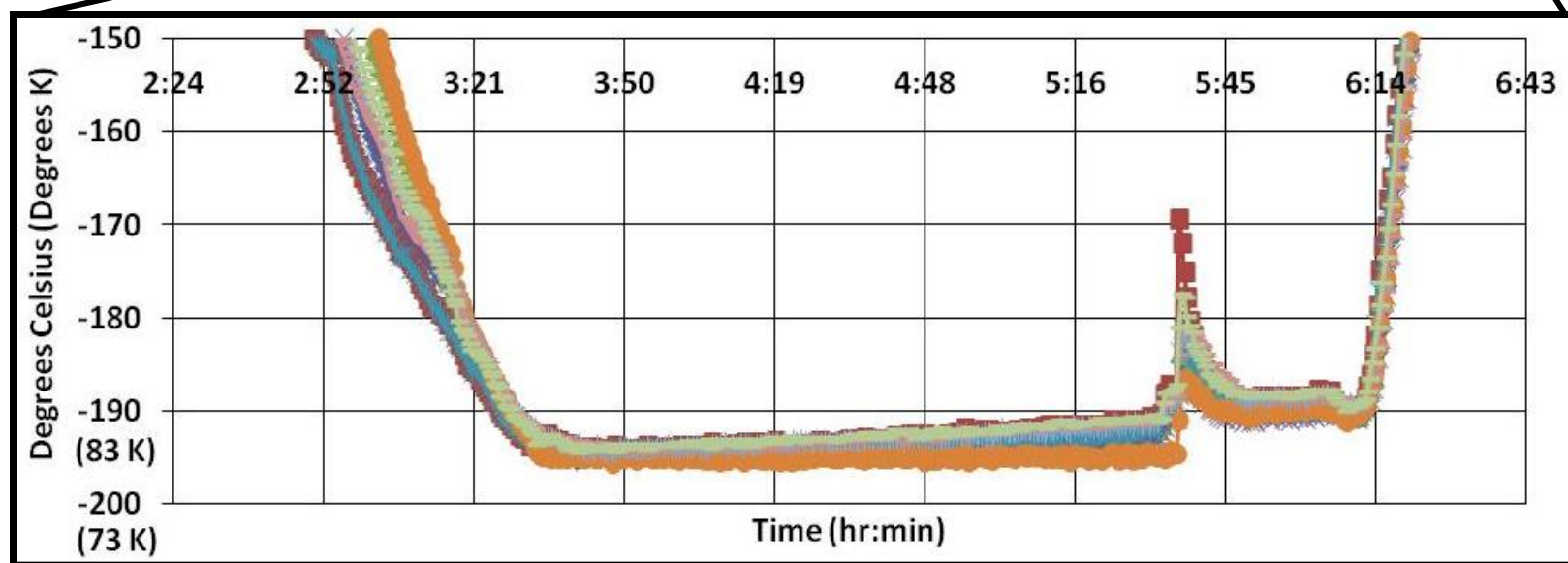
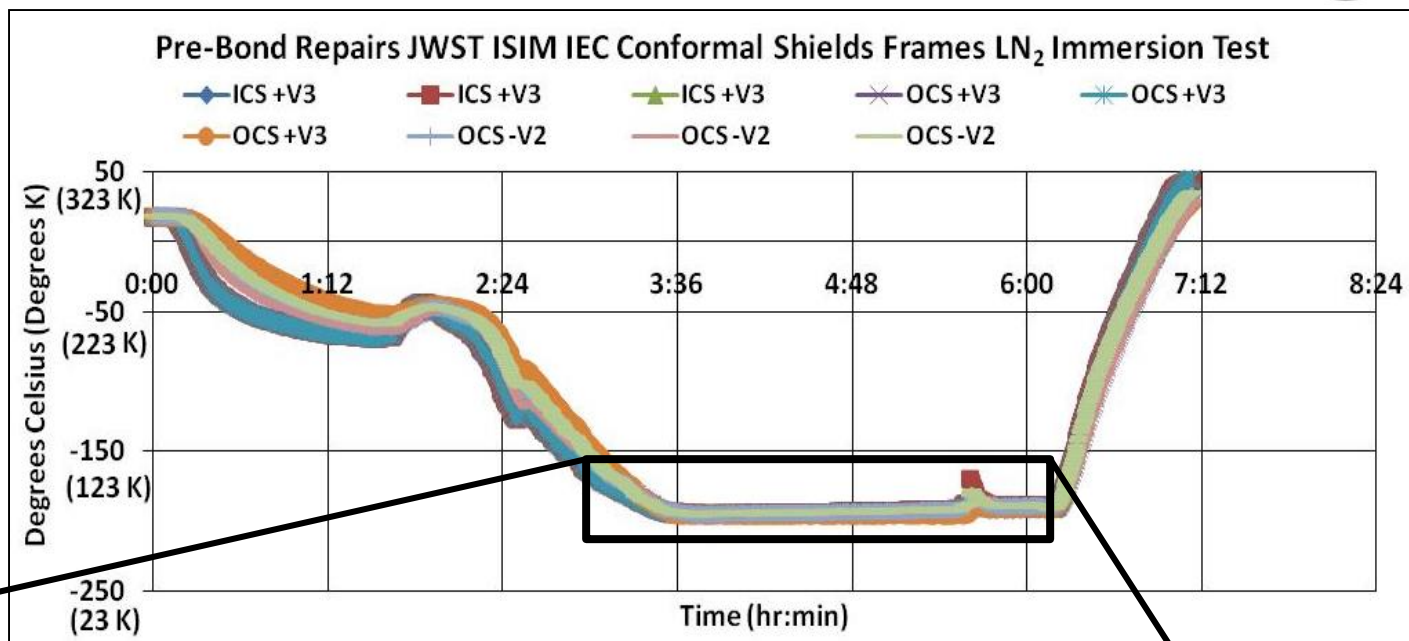


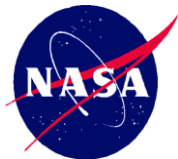
# Repaired Bonds Test & Results



(1) Thermal results:  
Achieved 78K-  
80K, exceeds  
protoflight  
levels

(2) Mechanical  
results positive:  
NO BOND  
FAILURES





# Conclusions

---



- **Bond integrity changes from ambient to cryo-conditions**
- **Must test all composite structures**
  - **Critical for mission assurance**
  - **Thermal & mechanical testing**
- **Perform “proof-of-concept” test runs on non-flight items**
- **Eliminate fillets during squeeze-out during bonding process**
- **Atmospheric LN<sub>2</sub> test method proved effective and efficient for achieving target test levels**

**Matt Stephens (co-author)**

**Leon Tilwick**

**Mike Bullinger**

**Janci Viegas**

**Larry Dumoncelle**

**Anthony Passaro**

**Clay Pollard**

**Yan Lui**

